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METHOD AND DEVICE FOR
STABILIZING SLIT FLUID JET

TRANSLATOR'S DECLARATION

Assistant Commissioner for Patents,
Washington, D.C.

Sir:

I, Toshio NISHIZAWA, declare:

that I am thoroughly familiar with both the Japanese and English languages;

that the attached document represents a true English translation of International Application No. PCT/JP00/02776 filed April 27, 2000; and

That I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signed this ______ day of ______.

Toshio Nishizawa

TRANSLATOR

Toshio NISHIZAWA

DESCRIPTION

METHOD AND DEVICE FOR STABILIZING SLIT FLUID JET

Technical Field

The invention of this application relates to a method of stabilizing a slit fluid jet and a device therefor. More particularly, the invention of this application concerns a method of stabilizing a slit fluid jet and a device therefor which are useful, especially for preventing fluid and solid from entering into a space of control from outside it, or for preventing fluid and solid from going out from the space of control into outside it.

Background Art

In a prescribed space of control of a building structure, a mechanical apparatus, etc., a slit fluid jet has hitherto been used as means for preventing fluid and solid from entering into the space of control from outside it, or for preventing fluid and solid from going out from the space of control into outside it.

For example, in a general type of building structure, an air curtain that is a kind of slit fluid jet is ejected at each of the inlet and outlet thereof to thereby make effective the zoning between the space of control and the external air, thereby the air-conditioning efficiency is successfully enhanced.

Also, in a processing apparatus for frozen food, air

curtains are ejected from the surroundings of a processing part thereof, to thereby form a space of cool air for the low-temperature preservation of foodstuff.

Further, in a machine tool, liquid curtains or shower curtains are ejected from the surroundings of a machining part thereof, to thereby prevent cut shavings from being scattered, or splashing out, from the space of machining. And this slit fluid jet such as the air curtain, liquid curtain, or shower curtain is formed by ejecting fluid from an apparatus using a pair of smooth flat surfaces or curved surfaces or an apparatus wherein the nozzles are arrayed.

However, although the above-described slit fluid jet has greatly contributed to forming the space of control, has a lot of problems from the viewpoint of efficiently forming a large space of control.

Namely, to form a large space of control through the use of such slit fluid jet, it is necessary to increase the velocity of that slit fluid jet. However, generally, increasing the velocity of the fluid results in that the instability of the film of the fluid increases. This raises the problem that the filmy fluid of the slit fluid jet becomes likely to be broken.

This likeliness to break of the fluid film of the slit fluid jet is attributable to the turbulence component (variable speed component) the fluid has. This turbulence component causes the exfoliation of the shearing layer on the inner wall of the slit, the creation of the exfoliation vortexes, the entrapment of air at the outlet of the slit, etc. It thereby

makes the thickness of the fluid film of the slit fluid jet uneven, with the result that the fluid film becomes broken due even to a small intensity of disturbance.

On this account, as one of the countermeasures against this, it is thought to be available to decrease the velocity of the slit fluid jet to thereby stabilize the film of the fluid. However, making the velocity of the fluid low results in that the fluid film is broken even by a small intensity of disturbance.

Also, further, the above-described likeliness to break of the fluid film becomes serious as the distance as measured from the slit opening increases. Namely, as the distance from the slit opening increases, the thickness of the slit fluid jet becomes very small, so that it is easily broken due even to a very small magnitude of disturbance.

In order to take measures toward the problem of the above-described likeliness to break of the fluid film, nowadays, in general, making thick the fluid film of the slit fluid jet is done. However, this means increasing the flow rate of the slit fluid jet but this becomes a factor causing a rise in the running cost.

Whereupon, the invention of this application has been made in view of the shortcomings of the conventional techniques mentioned above, and an object of the present invention is to provide a method of stabilizing a slit fluid jet and a device therefor which enable a stable fluid film to be formed from the ejection opening of the slit over a long distance with that slid fluid jet being not broken.

Disclosure of Invention

The invention of this application, as means for solving the above-described problems, first, provides a method of stabilizing a slit fluid jet, comprising superimposing a fluid jet accompanied with a flip-flop phenomenon upon one, or both, of the surfaces of a slit fluid jet and thereby forming a stable said slit fluid jet.

Further, the invention of this application, secondly, provides a stabilizing device for stabilizing a slit fluid jet, the stabilizing device being adapted to stabilize the slit fluid jet, comprising being equipped with two flat plates that oppose each other with a prescribed gap in between, one of the flat plates of the slit having an opposing surface that is smooth, the other having a network structure that has a plurality of crossed grooves that are crossed like a letter x. It, thirdly, provides a stabilizing device for stabilizing the slit fluid jet, wherein at an outlet of the fluid there are disposed flow passages of the network structure so that the fluids may be merged in. And it, fourthly, provides a stabilizing device for stabilizing the slit fluid jet, wherein the length between an detouched vortex, occurring at the back of the crossed groove portion, and a point to that the detouched vortex has been shifted is equal to or greater than the length of one side of a diamond-shaped protruding portion that is formed by the x-shaped grooves.

Brief Description of Drawings

Fig. 1 is a schematic diagram illustrating the present invention;

Fig. 2 is a plan view illustrating a flow structure of the present invention;

Fig. 3 is a plan view illustrating a flow structure of the present invention; and

Fig. 4 is a schematic diagram illustrating a flip-flop phenomenon that is a basic conception of the present invention.

It is to be noted that the symbols in the figures represent the following.

10 flat plate

11 crossed groove

12 buffer region

13 fluid supply pipe

14 air bubbles

15 vortex

Best Mode for Carrying out the Invention

Generally saying, the instability of the fluid film is attributable to the turbulence of the flow, i.e. the variable speed component. A fluid necessarily contains this variable speed component. Therefore, extreme difficulties are encountered in eliminating that turbulence.

On that account, the invention of this application has performed hydrodynamic control with respect to the conventional simple slit fluid jet. More specifically, the invention of this

application, in order to make uniform the non-uniformity of the fluid film thickness that results from the turbulence of the fluid, has formed a fluid film that has a two-layer structure of a slit fluid jet flow and a flip-flop flow. The invention of this application has resultantly added a mechanism for absorbing, with the lapse of time, the variable speed component that is contained in the slit fluid jet flow. In this respect, the invention of this application has a great characterizing feature.

In the process of reaching the present invention, the inventors of this application have initially thought that, if a phenomenon peculiar to a fluid that occurs utilizing the variable speed in it as the energy of it is superimposed upon the slit fluid jet flow, a stable fluid film will be formed. Based on this idea, the inventors of this application has conceived the fact that an detouched vortex, which appears in the flow at the back of a substance and which is typically represented by a Kalman vortex, periodically occurs due to the existence of the variable speed component.

Namely, when a substance has flow passages that have been disposed in a zigzag way, at each of the crossed portions thereof there occurs the flip-flop phenomenon that periodic vibrations occur in the radial direction of the flow. This flip-flop phenomenon is the mechanism for absorbing the variable speed component with the lapse of time, and that that flip-flop phenomenon is known as converting that variable speed component to the periodic vibrations that occur in the radial direction

of the main flow.

And, the inventors of this application have applied that flip-flop phenomenon to actual stabilizing of the slit fluid jet flow, and have thereby come to the present invention.

Regarding the method of stabilizing the slit fluid jet flow according to the present invention, more specifically, if causing a fluid to be ejected from the slit opening to thereby form a slit fluid jet, superimposing a crossed flow, which is followed by the flip-flop phenomenon, upon this slit flow jet, and thereby causing the variable speed component energy of the slit fluid jet to be absorbed into the vibration component of the flip-flop crossed flow, a stable fluid film is formed. The flip-flop crossed flow is formed by means of a network terminal formed by a plurality of crossed grooves and causes the jet flow to periodically vibrate in the radial direction of it. This periodic vibration is caused by the flow of the fluid and this periodic vibration is amplified by the interaction between the ejected pieces of flow. This groove flow structure that is constructed of a plurality of groove flows acts to convert the turbulent component of the fluid into the periodic vibration component that is active in the radial direction of it.

Namely, the network structure that is comprised of the flow passages formed by the grooves controls the turbulent component of the fluid, and causes the flip-flop phenomenon to occur at each of the points of merging of the groove flows and causes each of the groove flows to periodically vibrate in the radial direction of the groove.

The slit fluid jet upon which this flip-flop crossed flow is superimposed becomes stabilized. This is because, if the jet flow followed by the flip-flop phenomenon exists on any one surface of the liquid film of the slit fluid jet, the component of fluctuation of the slit fluid jet is converted into the flip-flop phenomenon energy that is active upon that jet.

A device for stabilizing the slit fluid jet according to the present invention includes, as an aspect, the one that has been illustrated in Fig. 1.

This stabilizing device for the slit fluid jet is constructed of two flat plates (10) that oppose each other with a prescribed spacing in between. The inside of one of those flat plates is smooth while the other thereof has a network structure that has a plurality of crossed grooves (11) the configuration of that is shaped like a letter x.

And, preferably, the flow passages of the network structure are located so that the pieces of fluid may merge in the flow-out opening of the fluid, and it is preferable that the distance from an detouched vortex appearing at the back of each of the crossed portions to the point to which that detouched vortex has been shifted be equal to or greater than one side of the diamond-shaped protruding portion formed by the x-shaped grooves.

Incidentally, although it is preferable that the flat plates (10) be flat surface members, they may be curved surface members. In that case, that the clearance that is the gap between the opposing members be equal, preferably, is made the

requirement.

Also, a buffer region (12) for the fluid may be formed at one side of the clearance. The fluid that has been supplied from a fluid supply pipe (13) is allowed to flow between the paired opposing members, and this fluid is ejected as a slid fluid jet.

Fig. 2 is a view illustrating, as a plan view, the member inside the slit that has a network structure. This member has provided therein as the passages of fluid a plurality of grooves 1a, b, c, ..., n and a plurality of grooves 2a, b, c, ..., n in the way both form net meshes. The respective ones of the grooves 1a, b, c, ..., n are provided at equal intervals and in parallel with one another, and the respective ones of the grooves 2a, b, c, ..., n are also provided in the same way.

A plurality of grooves that are included in the angular region (A) defined between the flow and the main axis and a plurality of grooves that are included in the angular region (-A) that has been similarly defined are provided each in paired relationship with each other so that the pieces of fluid may merge together to go out from the ejection opening. Namely, they are provided so that the fluid that has been supplied from an inlet portion (IL) of the fluid may merge together at an outlet portion (OL). As a result of this, they make out, at the merging portion, the fluid jet having the periodic vibration component that is active in the right and left direction of the drawing sheet.

In Fig. 3, since the fluid is being supplied under a

prescribed pressure from the buffer region, the fluid flows into the groove 1c as a fluid jet L1a and the fluid flows from the groove 1b as a fluid jet L1b. And the two pieces of liquid flow merge at a crossed passage M1. As a result of this merging, the flow speed is accelerated, whereby at this crossed portion there is a point of energy supply where the flow speed is maximum and the pressure is minimum. At the back of that crossed portion, there are formed asymmetrical detouched vortexes. These asymmetrical detouched vortexes at the back of that crossed portion are affected by the point of energy supply and, with the lapse of time, their position and shape are changed, whereby those asymmetric detouched vortexes alternately appear at the positions of V1 and V2 (see Fig. 4 too). The period in which they alternately appear depends upon the Strouhal number that is almost in inverse proportion to the Reynolds number.

A further explanation will now be given of the details of the flip-flop phenomenon that is the important basic principle of the present invention.

This flip-flop phenomenon is based on the utilization of the fact that the speed fluctuation at the back flow of a substance has periodicity. For example, when there is a substance in the course of the flow whose speed is V, the vortexes that mutually rotate in opposite directions alternately occur from that substance and flows backward. For this reason, periodicity occurs in the fluctuation of speed in the back flow of the substance. The frequency at which those vortexes occur is given by the dimensionless Strouhal number St = f L/V, where the f represents

the frequency in the periodic fluctuation phenomenon of the fluid; L represents the projection length of the substance toward the surface vertical to the flow (in general the significant length of the substance configuration. If that substance is a circular columnar member, the diameter of it); and V represents the speed of the fluid. For example, that the electric wire is sounded cracked on the strong wind of day is the phenomenon that that vortex is released.

In general, the Strouhal number depends upon the configuration of the substance. In the case of, for example, a circular columnar member, it is known that when the Reynolds number is from 1,000 to 100,000, the Strouhal number is 0. 2.

In the natural world, there is a living being that well utilizes the nature that periodicity exists in the vortexes at the back flow of a substance. Lighthill describes in his [Mathemetical Biofluid mechanics, Society for Industrial and Applied Mathematics, 1975] as follows. A group of fishes that takes a network structure of x-shaped meshes, which while being situated at a diagonal position are swimming at the back of fish, tends to decrease the resistance applied to that group of forwardly moving fishes through the use of the periodic vortex flows that are released from the fish that is going ahead.

Especially, the positional relationship in the network structure of x-shaped meshes acts to make the vortexes keep having their periodicity, while making the energy thereof keep increased. Accordingly, it is thought that the network structure of x-shaped meshes, which is formed by a plurality of crossed grooves, will

be useful, from the viewpoint of such a natural phenomenon as well.

Next, using Fig. 4, an explanation will be given of the flip-flop phenomenon that occurs in the flow in the network structure of x-shaped meshes. In Step 1, there is illustrated a state where an air bubble (14) begins to occur at the right/upper position of the network structure of x-shaped meshes. Step 2 illustrates a state where 0.3 second has lapsed from Step 1. In this state, that air bubble becomes large and resultantly the vortex enlarges. Step 3 illustrates a state where 0.3 second has further lapsed from Step 2. In this state, that vortex exfoliates and flows away to the back side. Simultaneously with this, it has been observed that a vortex (15) occurs at the right/lower position of the network structure of x-shaped meshes. In Step 4, this vortex enlarges and in Step 5 that vortex exfoliates.

In that way, the exfoliation of vortex periodically occurs to thereby cause the occurrence of the flip-flop phenomenon that vertically vibrates the jet flow at the backward opening of ejection.

Also, in the flows in the interiors of the network grooves that are formed by a plurality of the crossed grooves, not only the periodic vibration phenomena of the jet flow that occur at the network terminal but also the interaction between the pieces of ejection of the fluid occur in various ways. That interaction includes, for example, the appearance of the Lamb effect (the ultrasonic vibrations appearing on the surface of a

small-thickness solid), the vibration phenomenon of a shear layer caused to appear due to the conflict between the pieces of flow, the attraction characteristic appearing due to the detouched vortexes, and the Coanda effect.

Hereinafter, an embodiment of the present invention will be shown below and the invention will be explained in more detail.

Example

Using actually the stabilizing device for a slit fluid jet according to the present invention, a slit fluid jet was formed and its behavior was observed.

In this device, the width was 1 m, the angle of the groove was 15 degrees, the width of the groove was 2 mm, the depth thereof was 1 mm, and the clearance between the network structure of x-shaped meshes and the surface having no such network structure was made 0.5 mm.

When water was jetted from the slit at a flow speed of 0.5 m/s, a stable film of water with no broken portion existing therein was formed over a length of 1000 mm. In addition, the thickness of that water film on an upstream side thereof was substantially the same as that of it on a downstream side thereof. The amount of water at that time was 30 liter/min.

On the other hand, regarding an ordinary slit fluid jet having no network structure, experiments were conducted with the flow rate being made the same. As a result, breakage occurred at the position in the vicinity of 20 mm and, at the same time, the thickness of the water film became extremely great toward

the downstream side of it. To make the stable liquid film keep extending up to a position 1000 mm downstream of it when it was prepared from the ordinary slit fluid jet, an amount of water of 200 liter/min. was needed.

Using air, the same experiment as in the case of water was conducted at the flow speed of 5 m/s. The resulting air jet was visualized using an argon laser sheet. In the case of the ordinary slit fluid jet, a breakage phenomenon occurred at a position 15 mm downstream of the film, whereas, in the case of the slit fluid jet flow ejected from the invention of this application, a stable air film was formed up to a position 650 mm downstream of it.

Industrial Applicability

As has been explained above in detail, according to the invention of this application, a stable fluid film is formed from the opening of ejection over a long distance with the slit fluid jet being not broken in the mid-course of it.

CLAIMS

1. A method of stabilizing a slit fluid jet, comprising superimposing a fluid jet accompanied with a flip-flop phenomenon upon one, or both, of the surfaces of a slit fluid jet and thereby forming a stable said slit fluid jet.

2. A stabilizing device for stabilizing a slit fluid jet, the stabilizing device being adapted to stabilize the slit fluid jet of claim 1, comprising being equipped with two flat plates that oppose each other with a prescribed gap in between, one of the flat plates of the slit having an opposing surface that is smooth, the other having a network structure that has a plurality of crossed grooves that are crossed like a letter x.

3. A stabilizing device for stabilizing a slit fluid jet according to claim 2, wherein at an outlet of the fluid there are disposed flow passages of the network structure so that the fluids may be merged in.

4. A stabilizing device for stabilizing a slit fluid jet according to claim 2 or 3, wherein the length between an detouched vortex, occurring at the back of the crossed groove portion, and a point to that the detouched vortex has been shifted is equal to or greater than the length of one side of a diamond-shaped protruding portion that is formed by the x-shaped grooves.

ABSTRACT

A method and device for forming a fluid film stably over a long distance from a nozzle without breaking a slit fluid jet by allowing fluid flow out from a slit to form a slit fluid jet, superimposing a crossed flow causing a flip-flop phenomenon upon the slit fluid jet, and making the energy of the fluctuation velocity component of the slit fluid jet be absorbed into the vibration component of a flip-flop crossed flow so as to form a stable fluid film.

Fig.1

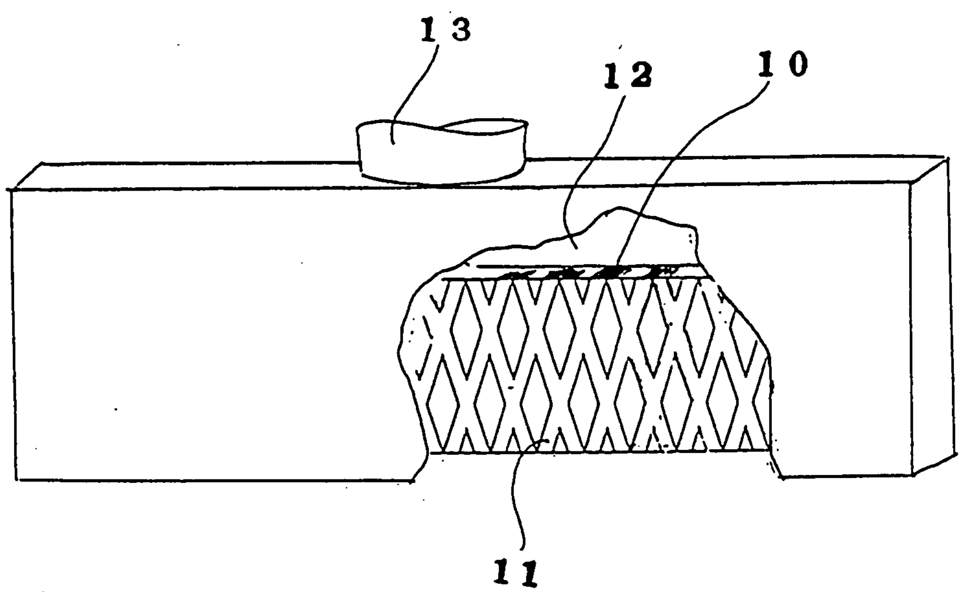

Fig.2

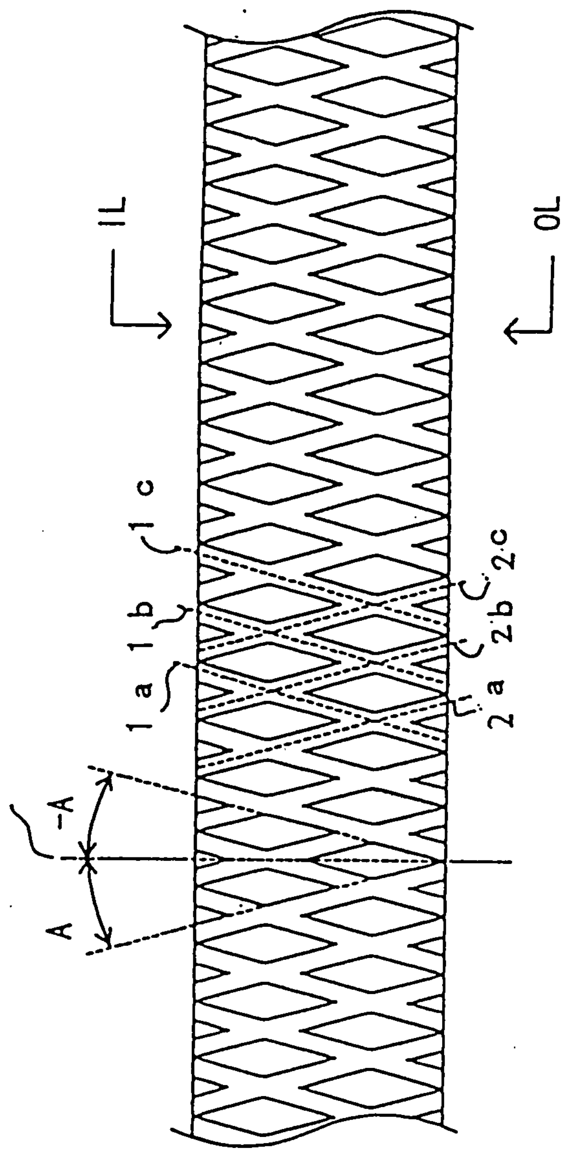

Fig.3

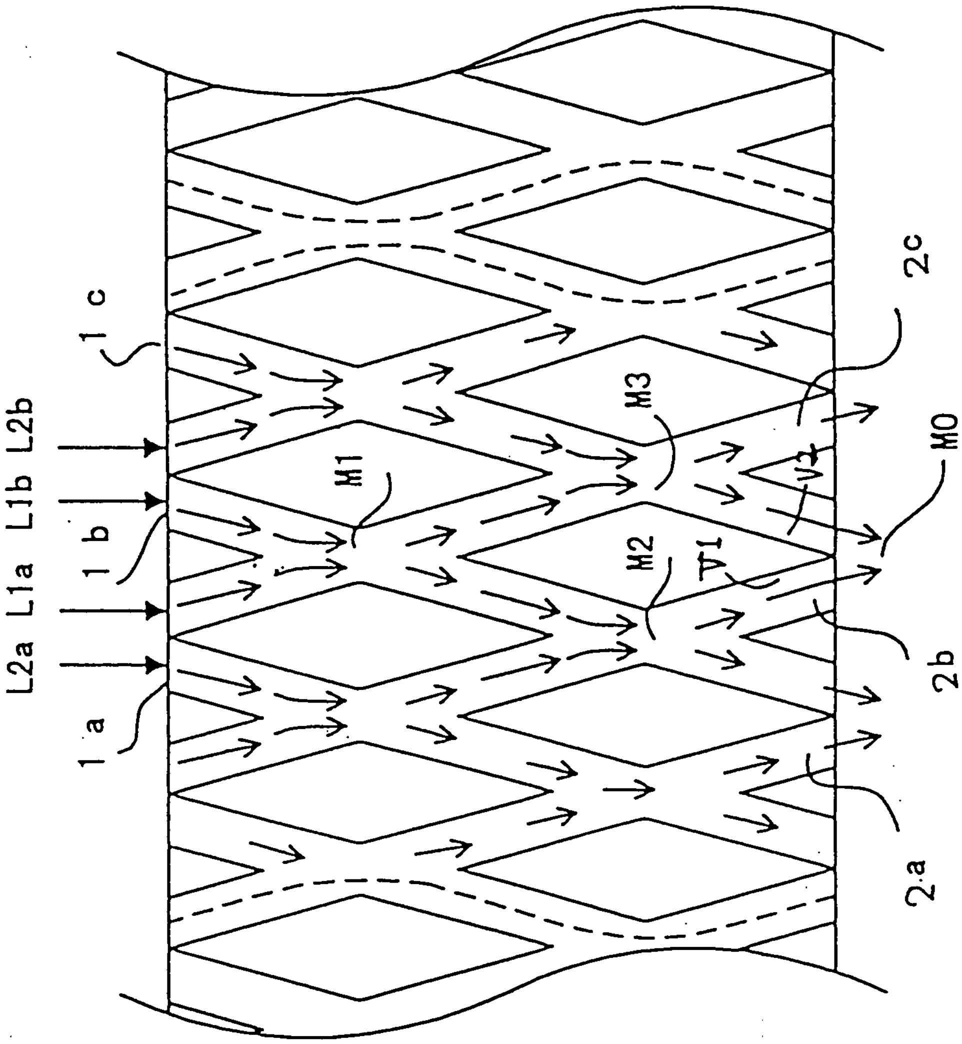

Fig.4